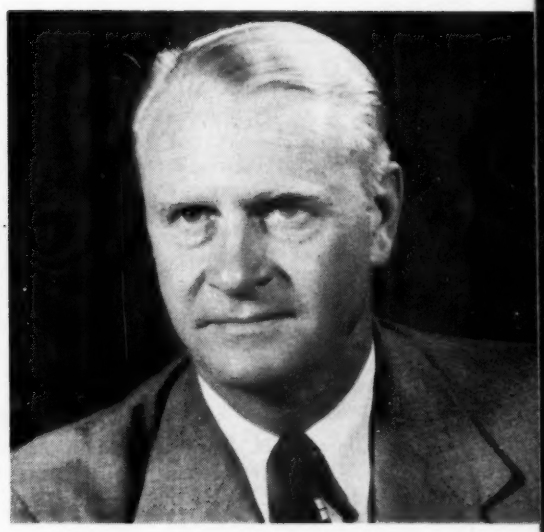
February, 1953

The Air Line Pilot

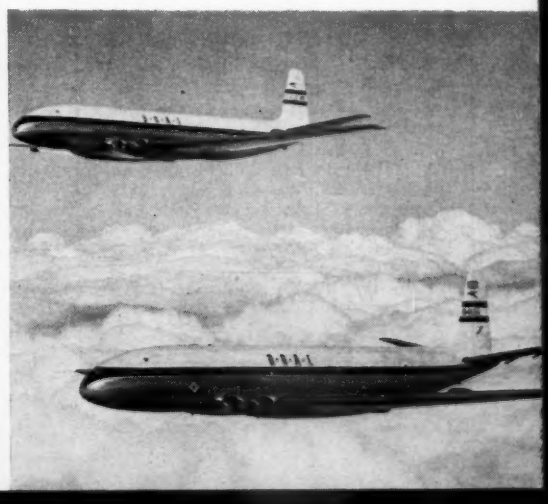
Cockpit Design and Safety

What's Ahead in '53?



Fifty Years of Flight

The Advancement of air transportation has been aided greatly by ALPA specialists; among them W. W. Moss (Lower left) and V. A. Peterson.



Cockpit Design and Safety

Statistical analyses of accidents indicate pilot error to be the commonest cause; however, a careful study of such statistics reveals a wide variety of types of error. Some of these are basic errors in judgment or in flying technique, but the great majority involves mistakes in cockpit procedure or in the use of controls, or misinterpretation of instrument readings or warning signals. In such cases, it is true that immediately preceding the accident the pilot committed an error, but frequently careful analysis reveals that an earlier error had been made in design, making the pilot's error highly probable under some given set of conditions. It is the purpose of this paper to analyze such accident potential and to indicate means by which it can be reduced.

William I. Stieglitz
Republic Aviation Corporation

The Man-Machine Relationship — The increased size, speed, altitude, and range of the modern airplane have resulted in a continually increasing complexity of instrumentation and cockpit controls. Only one element in the cockpit remains unchanged and unchangeable—the pilot.

The man who is flying the airplane of today, and who will be flying the airplane of tomorrow, is fundamentally the same as the man who, a few years ago, was flying a 100-m.p.h. stick and throttle airplane. His attitudes have changed; he is more willing to face complex situations involved in operating mechanical devices. He is, however, subject to the same basic limitations. His mental and physical reactions are fundamentally the same, and his reaction time is unchanged.

The result of this combination of the unchanging man and the increasingly complex machine has been that at times the demands placed upon the man have exceeded basic human limitations, and accidents have occurred. Many such accidents can be prevented. This can be achieved only by design that gives full consideration to both the abilities and the limitations of the pilot.

Environmental conditions and operating requirements are considered throughout the design of an airplane, not only as affects the aerodynamic characteristics and structural loads but also with regard to the installation of equipment. In many cases, equipment is not available which will operate under the environmental conditions of the airplane; in such cases, the engineer modifies the local environment to meet the requirements of the equipment. This same approach has already been applied to some extent to the pilot's physical environment; cabin air conditioning and pressurization, and proper seating, are a few examples. Physical limitations are only one part of the human factor: it is necessary that similar consideration be given to the pilot's psychological patterns.

Knowledge of these patterns, of the basic nature of man, is therefore essential. Fortunately there is much pertinent information available as a result of research in the field of Human Engineering, which has been defined by Beals as "the application of psychology, physiology, medicine, anthropology, and engineering to the Man-Machine relationship—or in this instance the Aviator-Airplane combination, primarily."[1]

We have not in the past made full use of the data derived from research in this field. Many costly errors could have been avoided had we done so. We must, in future design, make full use of the data already available and of that which will result from continuing research.

The Problem— Any engineering problem must be defined before it can be solved. In this case, definition of the problem requires an examination of the ways in which the increasing complexity of the airplane has affected the unchanged pilot. Basically, these can be put under three main headings.

First, the airplane has greater speed, range, and endurance and flies at higher altitudes. Further, higher wing loading has resulted in larger maneuvering radii. As a result of these factors the pilot has less time to make decisions, and must be more accurate because of the decreased margin for error; if a mistake is made, there is little time to correct it. In addition, high - altitude, high - speed flight is resulting in new navigational problems, which are being further complicated by the advent of in-flight refueling, with its associated requirement for pinpoint rendezvous.

Second, the improved performance described above and more

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W. Johnston, Editor

complex functional systems have resulted in a greatly increased amount of instrumentation, including not only flight and engine instruments but warning signals and eletronic equipment. Thus the pilot is being provided with more information, from more sources. All of this information must be recognized, analyzed, and correlated.

Third, the number of controls in the cockpit has increased correspondingly. Frequently a complex sequence of control manipulation is necessary. Test data have shown that human reaction time definitely increases with the number of stimuli and the complexity of the discrimination to be made.[2] Therefore both the increased amount of instrumentation and the greater number of controls tend to increase the time required for the pilot to assess a situation and take the necessary action. Thus, the combined result has been that greater precision is demanded of the pilot, less time is available to him in which to act, and yet he requires more time than previously.

Du Bois has pointed out that "when a pilot has been properly trained in flight, the instruments become part of a new sensory external nervous system, and the controls merely an extension of his motor system."[3] This appears to the writer to be more a statement of the goal to which we must work than of the situation as it exists today.

Instrument Displays. As applied to the problems of instrumentation, achieving this goal requires that information be presented to the pilot in a readily understandable form which does not require conscious interpretation. The inadequacy of present instrument display is well demonstrated by the fact that it requires approximately the same length of time to train pilot personnel in instrument flying as it does to train nonflight personnel.[4]

This demonstrates that proficiency in visual flight is of little value in instrument flight, in that the latter requires learning an enirely new system. Obviously, if the instrument display provided cues more like those of visual flight, not only would training be facilitated, but transition from visual to instrument flight conditions would be considerably simpler, and instrument flight would be less fatiguing than it now is.

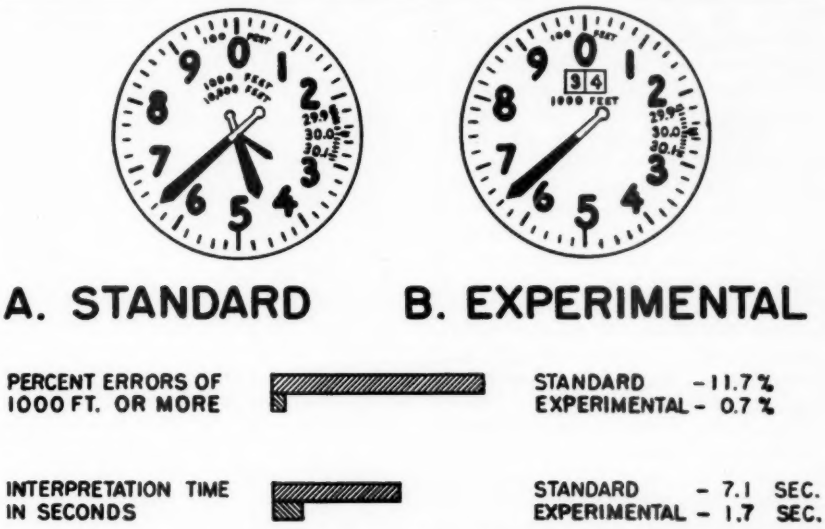


Fig. 1. Comparative speed and accuracy in reading a standard and an experimental altimeter.[6]

The ultimate solution to such problems must come not only from design and improvement of individual instruments but from the development of an integrated instrumentation system. There is no need here to dwell at length on this approach, since it has been presented by Beals.[4] Certainly, as Beals has pointed out, this is a problem that will require the combined efforts of psychologists, engineers, pilots, and flight surgeons and cannot be left solely to instrument specialists.

Development of such a system will require time. Meanwhile, there are other phases of the instrumentation problem toward the solution of which immediate steps can be taken. One is the elimination of the indiscriminate mixing of fly-to and fly-from indications, which require the pilot repeatedly to shift his frame of reference from the airplane to the ground and back again. Another is the improvement of the displays of those present types of instruments already proved to be unsatisfactory.

An example of this is the multiple-pointer instrument, such as the current standard altimeter. A survey made by Fitts and Jones of actual cases of misreading of instruments showed that 40 of a total of 270 incidents, or approximately 12 per cent, involved multiple - pointer instruments.[5] Subsequent tests, using Air Force pilots as subjects, revealed that the standard altimeter was misread by 1,000 ft. or more in 11.7 per cent of the cases and required an average interpretation time of 7.1 sec. Out of twelve altimeter readings presented to each of the pilots, one setting was misread by 68, and another by 51, of the 97 subjects.[6,7]

In contrast, an experimental-type instrument, with a single pointer and the thousands of feet shown on a Veeder-type counter, was misread in only 0.7 per cent of the cases, with a mean interpretation time of 1.7 sec. A comparison of the standard and experimental instruments is shown in Fig. 1.

Instrument Arrangement. Another aspect of the instrumentation problem is instrument arrangement. At long last, definite steps have been taken by the Armed Services and by the aviation industry to develop a standard grouping of the basic flight instruments. For several years, many air lines, the Air Force, and the Navy have had individual standard arrangements, but few, if any, of these standards have been the same. The use of airline equipment by the military in time of emergency and the increasing interchange of equipment among air lines emphasize the importance of the development of a single common standard.

The very fact that so many different standards have been in use,

with comparable safety, would indicate that as long as a well-planned arrangement is used the exact grouping is of less importance than the existence of a standard arrangement, so that the same instrument is always in the same location. It is desirable that the arrangement be such that the instruments most commonly used are most easily seen, and the most frequent eye movements are as short as possible.

A series of tests being conducted by the Air Force on pilot eye fixations during instrument flight[8,13] provides a sound basis for arriving at such a grouping. Most of these tests have been conducted using the current standard Air Force panel, but a comparison during ILS approach was made with an experimental arrangement. As might be expected, the change in arrangement had little influence on the frequency with which the pilot referred to the various instruments, or the length of the individual eye fixations: it did have a major influence on the sequence of instrument readings. Also, as would be expected, the tests indicate that what might be the optimum arrangement for one flight condition is not necessarily the optimum for others, since both the relative importance of instruments and the sequence of eye movements change.

Within the past few months, an industry group has arrived at a recommended standard instrument panel for commercial transport aircraft. Also, agreement has been reached between the Air Force and the Navy on a common standard. Certain differences exist between the arrangement adopted by the Armed Services and that recommended by the industry group. It is to be hoped that such differences be resolved in the near future.

Controls—and Accidents. The other major phase of the cockpit design problem concerns controls. Referring again to the Human Engineering concept, the controls should serve as an extension of the pilot's motor system. This requires that control motion be completely natural for the pilot so that his only decision need be what effect he wishes to produce, without the need for conscious determination of which control to move, where it is, and in what direction to move it. Selection of the proper controls is a matter of pilot training: control location, identification, and direction of motion are a matter of design. To what extent past design has been inadequate can best be seen by reference to the record.

In an analysis of 460 actual pilot errors in the operation of controls, Fitts and Jones[14] found that the errors were of six basic types. These types and the frequency distribution are shown in Fig. 2. The following description is quoted directly from the Fitts and Jones report:

"Substitution errors, in which the wrong control was operated, constituted exactly 50 per cent of all the error descriptions collected. The most common sub-types of errors under this general category were confusion of throttle quadrant controls (19 per cent), confusion of flap and wheel controls (16 per cent), and using the wrong engine control or feathering button (8 per cent).

"Adjustment errors and *Forgetting errors* each accounted for an additional 18 per cent of all errors.

"Three additional categories, *Reversal errors, Unintentional Activation,* and *Unable to Reach* accounted for the remaining 14 per cent of error reports."

The authors of the report point out that the frequencies with which the different types of error were described in the survey do not represent the precise frequency with which each type of error occurs. Further, this survey was conducted among military pilots, and a further variation in frequency distribution might be found if a similar survey were made of air-line pilots. Nevertheless, it appears that the types of errors would be the same and that the general relative frequency would not vary much.

In order to illustrate the sources of such errors, examples of various types of errors are cited below. These examples are not limited to those from the Fitts and Jones study.

Substitution Errors The pilot of a twin-engined aircraft, observing smoke from the left engine, feathered the propeller and shut down the engine. Immediately thereafter, power failed on the right engine and a crash landing resulted. In the investigation, it was found that in shutting down the left engine the pilot had turned off the fuel to the right engine instead of the left. In this airplane, all engine controls except the shut-off valves were installed in front of the pilot, and so arranged that the controls for the left engine were on the pilot's left, and those

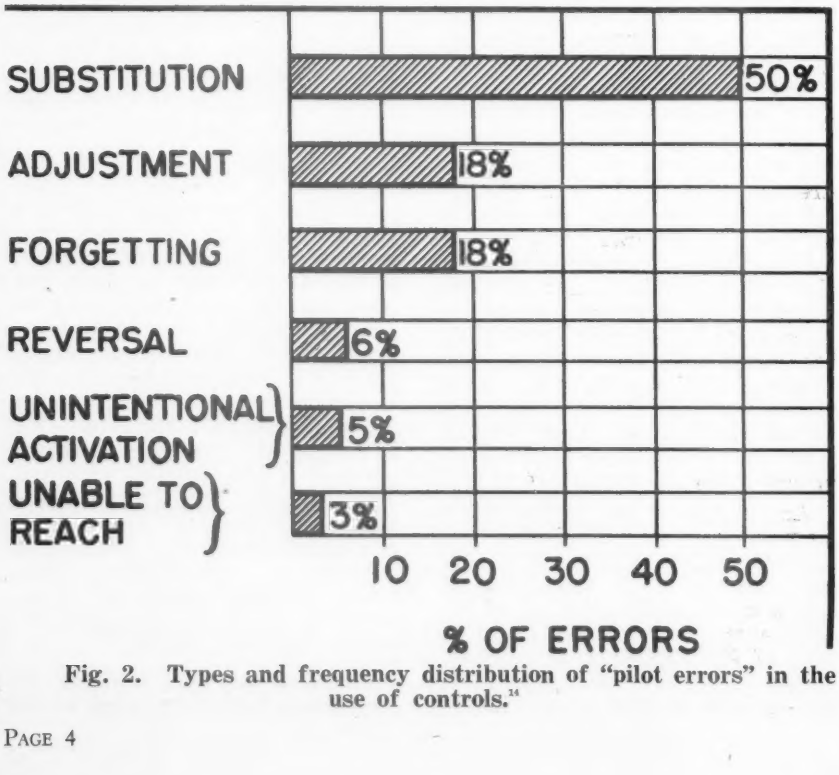


Fig. 2. Types and frequency distribution of "pilot errors" in the use of controls.[14]

for the right engine on the the pilot's right. The fuel shut-off valves, however, were installed along the left side of the cockpit, and so arranged that as the pilot faced them the fuel shut-off for the right engine was toward the pilot's left.

One of the commonest types of substitution errors has been confusion between flap and landing-gear controls. An example of this occurred following the landing of a transport aircraft at the end of a transoceanic flight. As the aircraft was taxiing in, the pilot signaled to the copilot to pull the flaps up. The copilot, who was on his first trip in this model airplane after extensive experience in a different model, reached over and pulled up the landing-gear control, which was in the same position as the flap control had been in the airplane with which he was familiar.

There are two effective and practical means of accomplishing this: shape coding of critical knobs to permit tactual discrimination, and standardization of location of controls. By the latter is meant not rigid dimensional standardization but rather that a given control always be in the same area and that controls be in the same position relative to each other.

In tests using typical throttle quadrant controls, Weitz definitely demonstrated the value of both of these measures. From one group of tests, in which visual cues were present,[17] Weitz concluded that "maintaining position of controls is of primary importance, yet if the position is changed and the shape of the handle remains constant, little loss in performance is encountered. The most efficient procedure is to maintain both position and shape constant."

In other tests, in which visual cues were eliminated,[18] coded knob shapes still provided a definite improvement in performance. Thus, even where spacing is completely inadequate to afford discrimination, fixed relative position is of definite benefit under conditions permitting visual reference. On the other hand, in a darkened cockpit shape coding is essential, and is of benefit at all times.

If coded knob shapes are to be of maximum value, they must be such as to be recognized immediately through the sense of touch alone. Tests conducted by the Air Forces resulted in a group of knob shapes meeting this requirement.[16 21] These, however, were arbitrary shapes, requiring that the pilot memorize which shape applied to which control. Thus while these shapes provide positive tactual discrimination, they furnish no associative cues. Such cues can readily be provided by shaping the knob to correspond to the unit being actuated, as, for example, a miniature wheel for the landing gear control and an airfoil section for the flap control. The Armed Services have adopted standard knob shapes for critical controls on this basis, using the arbitrary shapes resulting from the tests for controls, such as fuel mixture, for which there is no simple associative form.

Definite progress toward standardization of cockpit arrangement has been made. Standard control locations for single-place cockpits were established by the Armed Services a few years ago. Within the last few months, an industry committee and the Munitions Board Cockpit Layout Panel have come to complete agreement on similar standards for multiplace cockpits for military and commercial aircraft. Such joint agreement on knob shapes is also needed.

The Air Line Pilot welcomes comment on its editorial content

One factor to be considered in control location is related to the pilot's physiological rather than his psychological characteristics. One type of error noted above from the Fitts and Jones survey was labeled "Unable to Reach." Such "pilot errors" can be prevented by design that utilizes anthropometric data. On the basis of reach measurements, King has tabulated the maximum distances at which a large majority of pilots would be able to reach and operate manual controls.[22] Failure to consider such measurements is well illustrated by one multiengined aircraft, in which it was found that many controls were located as much as 15 in. beyond the fingertip reach of 50 per cent of the pilots. In this airplane only the side control panel was within normal reach.

The frequency with which this particular error has been a factor in accidents is also shown by Air Force statistics for the 22 months from January, 1943, to November, 1944. During this time, confusion between flap and landing-gear controls was a cause factor in 457 accidents, of which 184 occurred in fighters, bombers, and transports.[15]

Adjustment Errors The most frequent types of adjustment errors occurred in the use of fuel selectors, with the switch either being turned to an empty tank or being left in an intermediate position. Failure to obtain desired flap settings and improper trim adjustment are also common types. The effect of such errors is so readily apparent that there seems little need to cite specific examples.

Forgetting Errors A casual study might incline one to assume that the pilot's forgetting to operate controls would be primarily a matter of pilot training, and not of design. However, frequently such errors are the result of either the pilot's having too many duties to perform at a given time, or of unnecessarily complex procedures. One example occurred in a twin-engined transport in which the pilot in switching fuel tanks fed both engines from a single tank on cross feed, but then failed to turn off the nearly empty tank from which he had been drawing. Air sucked from this tank caused power failure of both engines and a forced landing. Simplification of fuel system controls or automatic fuel sequencing would have rendered such an error impossible.

Inadvertent Activation. As the pilot of a fighter aircraft retracted the landing gear after take-off, total power failure occurred, and the aircraft was landed wheels-up off the end of the runway. It was found that as the pilot retracted the landing gear, the main fuel shut-off, which was actuated by a toggle switch directly below the landing-gear handle, had been flipped into "off" position by the pilot's glove.

Reversal Errors During landing approach, the pilot of a four-engined aircraft signaled to the flight engineer for full-rich mixture. Immediate power failure occurred on all engines, and the airplane crashed short of the airport. In this particular type, the mixture controls

(*Continued on Page* 13)

The Air Line Pilot takes a speculative look at

What's Ahead For 1953

Jet Transports, Federal Control of Air Traffic, Contract, Renewals, an Air Safety Congress. All are problems in the coming year.

This year marks the fiftieth anniversary of powered flight. Only a half century ago, Orville and Wilbur Wright fulfilled man's dream of winged flight in a frail machine powered by a gasoline motor. The Wrights created a force in the economic and social development of the human race which is impossible to measure.

The airplane has collapsed time. The world today is a small one, in terms of time. We are only hours from the farthest spot on earth. The trading resources of the entire world are available to all because of the airplane. To accomplish this, an immense industry has grown whose problems are complex.

But while we are looking back, honoring the pioneers of the past fifty years, we must necessarily keep our thoughts also turned forward into the future. What is in store for the air line pilot in the year 1953?

Faster Than Sound. The jet transport is here. On May third of last year, British Overseas Airways completed the first scheduled passenger flight of a jet-powered Comet. The flight, from London to Johannesburg, S.A., a distance of 6,724 miles, was completed in 23 hours; 38 minutes elapsed time —but only 17 hours; 16 minutes actual flight. An average of 390 miles per hour in the air but only an average of 285 miles per hour block to block. Thus, the Comet cast a shadow over future air line pilot working conditions. The flight brought home to air line pilots the fact that the faster the airplane, the larger the ratio of ground time. And though jet transports are not scheduled to enter U. S. transport operation until at least 1954, the planning for their actual appearance must precede their arrival.

In an address before the Assembly of the RTCA, September 25-26, 1952, J. L. B. Selwood of the Cornell Aeronautical Laborator stated:

" . . . the turbo-jet airplane may be handled during the immediate future by greater piloting skill and more careful ground control and lead to one operator gaining a slight advantage over another, but, in the long run, the complexity of the entire operation will be increased and the mass utilization of the airplane will be delayed . . . "

His next statement should be of great interest to all pilots:

" . . . We predict . . . a three fold increase in passenger miles flown in the next ten years. Due to the increase in airplane speed and passenger capacity, the number of airplanes will increase by only 30 percent. However, air operations will increase by 100 percent . . . "

It is not in the pilots' best interests to work out the complicated controls of working conditions after the jet transports are put into operation.

Not only working conditions must be considered with the advent of the jet transport. Air line pilots must assure themselves that the airplane they will fly is the safest airplane which can be constructed at that time. The air line pilot is saddled not only with a responsibility to protect his own life, but with a greater responsibility to protect the lives of his passengers.

What does this require? Jet aircraft must be fitted into operational practices and aeronautical facilities. This cannot be adequately accomplished without actual in-service testing. Aeronautical facilities (airports, radio, navigational aids, meteorological information for high altitudes, etc.) and procedures must be adapted to the operation of jet aircraft.

ALPA has recently taken the stand that in order to assure itself that its members will be flying safe airplanes its members must have a voice in the construction and planning of the airplanes. With the industry entering the jet transport era, the operational knowledge of the men who fly the airplanes must be utilized in designing the jet transport. In process are ALPA's recommendations for the design of such an airplane. In 1953, the air line pilots will be able to advise with manufacturers of their expectations for the jet transport.

Schedule With Safety. In a recent address to members of the Flight Safety Foundation (ALP Dec-Jan), ALPA President Clarence N. Sayen stated: "We conceive one of the primary safety functions of the air line pilot to be the discovery and reporting of air safety problems."

Speaking to delegates to the ALPA 12th Convention, CAA Administrator Charles Horne said: " . . . the fellows who do the flying . . . I claim, collectively know more of the answers than any other place I can go to find them . . . "

Pilots know the answers; pilots should supply the answers. Pilots, individually and as a group are a great force for enhancing safety.

The backbone of ALPA's Safety Organization is the individual member who reports upon and works for the safe operation of his aircraft. To collect and activate the safety knowledge and recommendaitons of the individual pilots is the job of ALPA's Engineering and Air Safety Department and the Association's Safety Organization. The broad aims of the two are:

—Implementation of the policies of the Association in the field of air safety.

—Participation in industry projects and conferences which seek

(*Continued on Page* 11)

Looking Ahead

A statistician and researcher looks back at same dire predictions which failed to materialize; and ahead at the country's economic future.

By Ronald L. Oakman, ALPA Research Director

On the occasion of his 75th birthday, Carl Sandburg, the poet, said, "I'd like to stick around a while . . . the human race is a hardy bunch but the future is really going to be taxing." We are sure that the use of the word "taxing" by Sandburg was intended in a broad, general sense and was in no wise a snide political remark but in any event, we feel he has some merit in what he predicts. It is one thing, however, for a poet to make a broad, general prognosis of future events and quite another for a businessman, economist, or statistician. Wide variances exist in the forecasts made by the experts in the economic field whether it is for the next six months or the next six years. Even the future population growth of the United States is predicted according to three different formulae by the Bureau of the Census, and this is a basic factor in any economic prophecy. There is general agreement that we will have more people as the years go by but predictions vary from 165 million to 180 million concerning the probable total population of the United States in the year 1960.

It is interesting to note, too, that whereas in the 18th century, following the publication of the "Principle of Population" by Thomas Malthus, it was believed that unless we limited the human productive process, we would soon eat ourselves into an empty cupboard, economists today believe that our main hope and salvation lies in a large population growth. Due to the fact that the birth rate in this country has risen from an average of about 19 per thousand population in the period of the 1930's to an average of 24.9 per thousand in the postwar years, the nation has never before faced the potential demand for civilian goods and services that it does in the years immediately ahead. This increasing population outlook forecast by all demographers implies an increasing need for all consumer goods and services. This in turn implies increased investment in manufacturing and service industries, expansion of the agricultural activities of the country, increased public construction for such items as hospitals, schools, highways, etc. (According to the American Association of State Highway Officials, the Federal Aid Highway System alone needed more than $32 billion worth of highway construction as of the first of 1952.)

Much Conjecture is evident concerning the immediate future when the large governmental expenditures for defense are scheduled to level off. However, the tremendous backlog of unfulfilled needs mentioned briefly above indicates that the economy can shift quite readily as defense expenditures slacken to provide protection and consumer spending. If business does its share in providing goods at reasonable costs and by investment decisions helps to assure workers of continued, full employment and if the attitudes and behavior of businessmen, investors, and consumers is not one of fear or uncertainty, the economy should be able to go ahead without any artificial stimulus.

Early in 1952, when it became apparent that the air line industry was rapidly changing from the status of a government subsidy to that of an industry standing more or less squarely on its own merits subject to various regulations and assists, certain spokesmen for air line management began to publicize the fact widely that air line costs of operation were rapidly overtaking and exceeding air line income. Though this was true in certain instances, it created a reluctance on the part of investors to join in the floatation of additional air line stock offerings. The publicized protests were probably made in order to convince the CAB that higher fares were needed and applications were made by several of the leading air lines requesting elimination of the 5 percent round-trip discount and an addition of a $1.00 extra fare per trip. As time went on during the year, it became evident that the air line transport industry was not doing so badly in 1952 and the request for the elimination of the 5 percent round-trip reduction was dropped. As it looks now, air line revenue passenger miles were increased during 1952 by 17 percent over the amount for 1951 and though operating expenses did increase, operating revenues were almost 14 percent higher during 1952 than the year previous. The ATA forecast at the moment is for a 10 or 15 percent increase in air passenger travel domestically in 1953 over the figures for 1952. Barring certain "eventualities," as economists say, if we really are a "hardy bunch" the years ahead may be weathered without losing stride, taxing though they may be.

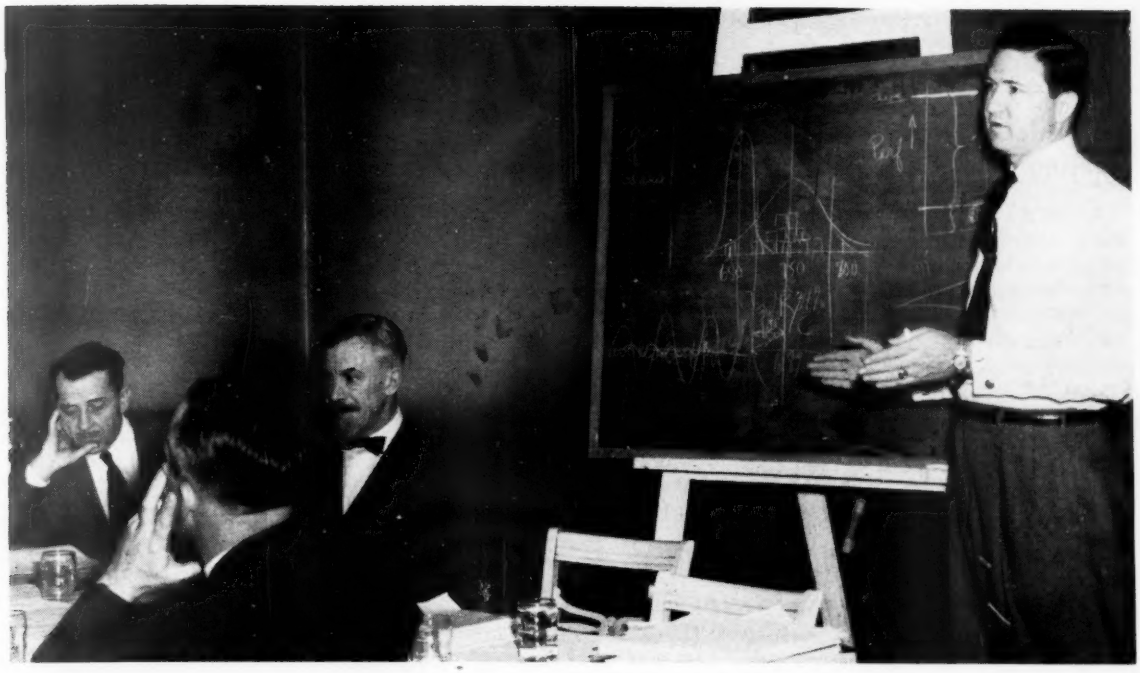
Camera

Performance Meeting For Future Regulations

The CAA-CAB Performance Study Committee met in Chicago with ALPA for a two day meeting to discuss the "rational method" of performance requirements.

(Story, Page 10)

Near blackboard, Jack Carran, CAA Aerodynamist; the three members of ALPA's Performan Study Committee, Jack Durham, Bill Moss, and Jim Talton; and ALPA's Carl Eck. H. Mouden with back to camera.



Left to right: Hugh Freeman, CAB Airworthiness Regulations Division; Jack Durham (Back to camera), AA member ALPA Performance Study Committee; Omer Welling, CAA Head of Aircraft Engineering; and at board, Ray Maloy, CAA Head of Flight Test Section.

Rear row, left to right, R. Justiss, NWA; J. D. Smith, CAP; H. Mouden, BNF-MCA; R. G. Stone, UAL; W. W. Owen, EAL. Front row, left to right, H. G. Portman, UAL; C. F. Eck, ALPA; J. P. Talton, EAL; W. W. Moss, PAA.

News

Performance Meeting

(Photos Pages 8-9)

A CAA - CAB Performance Study Committee has under study data on which to base "rational" performance requirements for transport type aircraft.

On January 21 and 22, ALPA representatives met with the CAA-CAB group in Chicago to review what has been done to date on this subject. The Performance Committee consisted of CAA's Ray Maloy (head of flight test), Chairman of the Committee; Homer Welling, CAA (Engineering Division) member; Jack Carran, CAA (Aerodynamist) member; Hugh Freeman, CAB (Bureau of Safety Regulations) member; and Stanley Nowlan, UAL aerodynamist, member.

Chairman Maloy explained to pilot representatives present that they had not reached final conclusions on all their work but the purpose of this meeting with ALPA as well as other industry groups was to gather study material for formulating regulations. Maloy anticipated having proposed regulations available for discussion at the 1953 Annual Airworthiness Review meeting to be held sometime in August at Washington, D. C.

Stanley Nowlan led a discussion relating to take-off problems, including climb out. The various configurations of take-off and climb out flight path were considered. The runway length is determined by the distance required to accelerate to the V1 speed and come to a stop, or reach a minimum height by the end of the runway by the continuous flight path analysis method (in many cases, in today's certification the segmented take-off flight path is used). This continuous flight path method will show how the enroute configuration is attained so that all acceleration and climb out problems are considered. Full temperatures and humidity accountability and other factors adversely effecting performance are to be considered for determining take-off runway length and obstacle clearance requirements.

Hugh Freeman led off for the discussion of the enroute performance margins. Mr. Freeman's discussion of enroute performance was based on discussions and reports of the ICAO meetings.

A summary of the conditions anticipated for enroute rules are as follows:

After Failure of a single power-unit. From each point along the route and planned diversions therefrom, it shall be possible in the event of one power-unit failure to continue the flight to a suitable airport and, on arrival at that airport, the net gradient of climb shall be not less than zero at a height of 300 metres (1000 feet) above the elevation of the airport.

Two engine aircraft limiting route conditions. Airplanes shall not be operated on routes where the product of the expected flight time from take-off to destination times the flight enroute to a suitable airport is greater than a certain figure.

Four engine aircraft limiting route condition. It shall be possible in the event of two power unit failures to continue flight to a suitable airport and arrive 1000 feet above the airport or an emergency airport within a certain maximum time.

Ability to comply with enroute criteria will be determined on the following basis:

—either the declared temperature for the route, or the forecast temperature for the route!

—the expected wind for the route;

—the scheduled net gradient of climb or gradient of descent after power failure appropriate to the weight and altitude at each point considered;

—a satisfactory positive net gradient of climb shall be avilable if the airplane is expected to gain altitude at some point in the flight after power failure has occurred;

—the minimum safe altitude appropriate to each point between the place at which power failure is assumed to occur and the airport at which it is intended to alight, is exceeded;

—in the case of failure of single power unit making reasonable allowance for indecision and navigational error in the event of power-unit failure at any point;

—it may be assumed that, if provision for fuel dumping is made, fuel will be dumped in a manner which allows suitable reserves for proceeding to, and missed approaches at, the airport at which in the event of the emergency considered it is planned to land.

The landing distance problem was discussed by Jack Carran of CAA. His review of the subject pointed out that the field length would be determined by the main landing distances required plus the factors influencing landing distance requirements. Variables in determining landing distances that were considered were: The threshold speed from actual photographic records, day VFR, day IFR, night VFR, and night IFR. Photographic data was analysized from U. S. records and those of European countries working on the ICAO Standing Committee on Performance. The process of gaining photographic records of landings is still continuing, to assist in collecting realistic data for regulation purposes.

In addition to determining rational landing distances, the balk landing condition is also receiving much attention. Data to date shows that a flap and gear down balk landing can occur within 50 feet of the ground once in 7500 approaches, and the chance that a flap down and gear down balk landing will occur under 100 feet is one in 2500 approaches. (Landing distance studies are based on 200 ft. ceiling and one-half mile visibility).

At the close of the meeting, the Committee stressed that all of their calculations and figures mentioned were of a tentative nature and were being used for exploratory purposes and did not represent any fixed conclusion at the present time. The CAA Performance Study Committee pointed out they had several problems confronting them and outlined a work program of assistance for them in finding solutions. The Committee would welcome any comment pointing out where their methods were not accurate for determining what is needed to establish rational performance requirements. The ground covered in the two day

meeting provided the pilot group with an introduction to the Committee's research efforts to date. Round table discussions were held on each subject and a general exchange of valuable information resulted.

Mr. Maloy, the Chairman of the Committee, pointed out that he would like to see a similar discussion with a pilot group sometime before May which will allow a period for additional study of all information gathered. The meeting ended with a joint agreement that much progress had been made in the direction of obtaining rational operating standards for performance; however, there was also agreement that much work had to be done before a satisfactory replacement of present performance operating rules would be on hand.

Those in attendance for ALPA were: The ALPA Performance Standards Committee: W. W. Moss, Chairman, PAA; J. P. Talton, EAL, member; J. Durham, AAL, member; W. W. Owen, EAL, Atlanta, Regional Air Safety Chairman; L. Mouden, Braniff, Kansas City, Regional Air Safety Chairman; J. D. Smith, CAL, New York, ALPHA Regional Safety Chairman; R. Justiss, NAL (proxy for Ira Bortles), Seattle Regional Air Safety Chairman; Dean Phillips, TWA, Chicago Regional Air Safety Chairman.

ALPA Engineering and Airworthiness Committee members: R. A. Stone, UAL, Chicago; H. G. Portman, UAL, Chicago; L. Meredith, AAL, Chicago; B. Hewitt, TWA Chicago; C. Daudt, AAL, Safety Chairman, New York; Charles Ruby, NA, Safety Chairman, Jacksonville; M. Fenello, EAL Master Chairman, New York; and C. N. Sayen, ALPA President; S. Camden, ALPA Vice President; T. G. Linnert and C. Eck, ALPA Engineering Department.

What's Ahead . . .

solution to problems important to the air transportation industry and the air line piloting profession.

—Representation of the pilot viewpoint in the formulation, drafting, or revision of Civil Air Regulations or any other action of municipal, state, federal, or international authority to regulate air commerce.

—Participation in the safety projects of the International Federation of Air Line Pilots Associations and monitoring of the actions of the International Civil Aviation Organization.

The successful operation of the Air Safety Structure is based on the premise that individual pilots will work actively within its framework. The structure is nothing more than a paper plan without the active interest of the individual pilot members. The framework is set up like this:

—Council Air Safety Committees handle problems which concern only the local council and disseminate information to their council.

—Central Air Safety Committees, composed of a representative from each council committee, handle problems common to more than one council or the entire air line.

—Regional Air Safety Committees, composed of representatives from each air line at a particular domicile, handle local problems requiring the coordination of the ALPA councils at the domicile.

With the organization operating smoothly and effectively in 1953 it should be a year of unprecedented accomplishment. The air line industry presents an ever-changing picture. Everyday there are new products, gadgets, procedures, innovations designed to improve air safety in commercial aviation. The pilots, as a group, must examine each product or procedure carefully to insure the maximum in air safety.

Entirely new to ALPA in 1953 will be the Air Safety Congress scheduled to convene in March. Funds were voted for the Congress at the ALPA 12th Convention. Reasons behind the move are:

—A national meeting devoted exclusively to the processing of technical safety problems.

—The Congress will help to provide ALPA representatives at industry meetings with up-to-date information and current policies upon which to base their actions.

—ALPA pilot representatives on special projects will have available an additional opportunity to consult periodically with a national group experienced in engineering and air safety activities.

Besides ALPA representatives, industry experts in many fields of aviation safety will be on hand to discuss problems with the Congress delegates.

Reestablishment of the Independent Air Safety Board will also be a primary target for ALPA in 1953. Behind the move:

—A separate Air Safety Board completely divorced from CAA and CAB would increase the opportunity for independent evaluation of all phases of air safety.

—No investigatory body should sit in judgment of its own cause.

Problems to be considered by the ALPA Air Safety Committees are many. Some will be new, some will be continuing. High priority problems for which solutions are needed concern:

—Prevention of Inadvertent Propeller Reversing. Airworthiness directives are being prepared by CAA which incorporate the ALPA suggested hydraulic high pressure relief valve making it impossible for propellers to reverse in flight. An alternative device which makes it possible to full feather out of on inadvertent reversal is being considered. Service testing in 1953 will be required to prove the worth of these two possibilities.

—Rational Aircraft Performance Standards. ALPA representatives will attend CAA-CAB—conducted meetings throughout the year to examine present standards and service-test the findings. ALPA's newly-formed Performance Committee composed of W. W. Moss, J. Talton, and J. Durham will continue their work in 1953. The Committee is studying maximum and minmum performance limits for transport aircraft.

—Radar Traffic Control will require careful monitoring and painstaking review of procedures as use spreads in 1953.

—Radio Technical Committee for Aeronautics. There will be many executive and technical sessions of the Committee in 1953. The overall plan for activation of the "common system" will require constant supervision and coordination with the pilot groups.

—Approach and Airport Lighting. This ALPA project has

Letters to the Editor

Sir:

Relative to the article "Cross-Wind Techniques" appearing in the November issue of the Air Line Pilot . . . . .

I would venture that ninety percent of all solo students are aware of the principles involved—or at least should be. If there are any of us who have progressed to line flying without being extremely aware of them, I think something is amiss.

. . . . I would sure hate to think that someone with a few hours in a Cub would read it and say "I thing I'll take the train next time —these guys ain't soloed yet!"

I think the magazine is fine, so won't you help me keep my blood pressure within limits?

NAME WITHHELD

Sir:

. . . it is Mr. A. W. Stainback's article "Space Cadets on the Loose" in the November 1952 issue which has me bothered, and in particular the Schlieren photos on page 15 showing a rocket (?) model at various Mach numbers. I should think that the three photos are not only captioned in reverse (believe highest Mach value ought to be at the top of the page), but that the values unscrambled are still moderate exaggerations. Almost by inspection, or by applying a a few lines and an engineer's scale, it would appear that the photo at the top was about Mach 4.2, that in the middle 3.7, and 2.3 at the bottom. Assuming that the main wedge-shaped (or conica) wave generated at the nose of the model as revealed by the Schlieren technique is indeed the primary compressibility wave, then we should be entitled to conclude that the Mach value for the test is simply the cotangent of ½ of the wedge angle. This would follow since the vertical component of the wave is due to elasticity only, hence equivalent to the speed of sound through the medium, and the horizontal component due only to the "compressing" of the model, or the relative velocity of the model to the airstreem. Perhaps even the apparent sharpness of the wave is a further clue, for one might suspect that the least induced damping effect would occur when the opposite branches of the wave are at right angles, or Mach 1.

One might further suspect that the slight curvature detected in the wave form in the top photo was due to the more pronounced heating effect, reducing the effective density of the medium in this region; and that the appearance of waves ahead of the model in the lower photo resulted from an obstruction in the tunnel or from sidewall reflections.

JOHN R. HAWLEY
(Council 50)

Sir:

It seems that the photos on page 15 of the November 1952 issue of the, as Sadie calls it, Hair Line Pilot, have been misstacked. The one on the bottom should be on the top and the top one should be on the bottom.

If one can get a schlieren photo of a missile, or of any object through a gas, the speed of the missile in terms of the Mach number can be determined at once. All that is needed is the measurement of a simple triangle, a right triangle. The axis of flight is determined, and that will usually be the axis of the missile; when it is not the axis of the missile it is half way between opposite sound waves. To the axis line a perpendicular is erected. If you are too tired to erect a perpendicular you may just draw a line at right angles to the axis line. Where this line touches the sound wave line, the triangle is completed. The sound wave line is the hypotenuse of the triangle . . . .

Going back to our schlieren triangle, it is clear that when the axis line of the triangle is the same length as the altitude line (the triangle now is 90 degrees, 45 degrees, 45 degrees) the missile is proceeding at the same speed as sound.

The Mach number can be measured pretty accurately by eye, without drawing anything. The actual speed in miles an hour is a function mostly of temperature, and that has to be known to give the figure in that scale.

It would have been most interesting to have put down the resistance at Mach 2.8, 4.6, and 6.3. You will note that there is less disturbance apparent in the high Mach than in the lower.

It is hoped that you will not take this piece on the missile amiss. I am no expert on missiles. The fact is that I will be glad to leave them alone if they will do the same for me.

HIRAM WILSON SHERIDAN

● **The mis-stacked photos are the fault of The Airline Pilot, not author Stainback.—Ed.**

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reached the implementation stage, with acceptance of the ALPA system by IF-ALPA, ATA, IATA, and ICAO. CAA has authorized the installation of a complete ALPA system at San Francisco. A target for 1953: Installation of a Maximum of Center Line approach light and standarization of existing systems.

—Aircraft Exterior Lighting. Probably coming up in 1953: An analysis of increased flashing rate installations and evaluation of more vertical fin anti-collision light installations.

—Cockpit Standardization. SAE Committee work on this subject is practically complete. The Committe may have time this year to transfer its decision into regulations.

—Emergency Evacuation. Studies during 1953 will continue to implement further ALPA recommendations.

—Cockpit Coordination. A Navigation Checking Indicator, developed by Larry Shapiro (UAL) is currently being evaluated and service tested by pilots of United and other carriers.

—Fire Hazards. Badly needed are fire warning devices which will not fail and which will not give false warning. ALPA's study of the devices will continue.

—Terrain Warning Indicator. A research project with various recommendations is being evaluated.

—Airport Vehicular Traffic. ALPA is working on standards to be established for vehicular traffic on airports.

—Cockpit Ventilation and Pressurization. Research is continuing to establish standards for ventilation in pressurized cabins.

Who Will Control? Do states and municipalities have the authority to regulate interstate air traffic, an authority assumed to be in the exclusive jurisdiction of the federal government? That question popped up first in 1949, with the now-famous Neuhauser case in which Captain Neuhauser was arrested by New York City police for allegedly violating an anti-noise pattern, may be resolved in 1953.

If cities can regulate the laws governing air transportation, ALPA contends, no pilot will be free of the possibility of being arrested and fined indiscriminately. Among air line pilots' specific woes would be:

—Triple Jeopardy. Pilots could be fined by the federal, state, and municipal governments for allegedly violating a single regulation.

—Compromising of Safety. Air traffic regulations could be drawn up by laymen whose prime object would be the reduction of noise. Trained technicians — aiming at air safety — would be forced to bow to laymen aiming for noise reduction.

—Pilots would be forced—under penalty of fine—to have a complete knowledge of air traffic rules set up by each individual municipality. For the pilot who daily crosses over hundreds of cities, an impossible task.

ALPA took its first steps to keep air traffic control in the hands of the federal government when it took on the task of defending Captain Neuhauser. Although the Captain was acquitted the constitutionality of the question of federal vs. municipal control of air traffic was not decided. But coming up in 1953 is a case which may bring an end to the lengthly controversy. On the books of Cedarhurst, N.Y., a city adjacent to New York International Airport, is a law banning flight over the village at less than 1,000 feet. The air above the Village is necessary for turning, approaching and manuevering by aircraft landing and taking off from all of the airport's runways. So far, ALPA and other interested groups have succeeded in obtaining a temporary injunction restaining the Village from enforcing the law. The injunction was recently upheld in the Circuit Court of Appeals. Early in 1953 the law is scheduled to be tested for its constitutionality.

One and One Makes One. 1952 furrowed a deeper wrinkle in the brow of the air line piloting profession—the merger. While the mergers may solve some of the companies' economic problems, they create additional ones for the pilots. Some measure of protection was obtained in 1952 with the success of having protective conditions imposed by the CAB in the Braniff/Mid-Continent; West Coast/Empire; and Delta/Chicago and Southern mergers. Protection, however, is only a small part of the problem. Seniority problems must be resolved — two contracts merged into one — councils reorganized. These problems remain in 1953.

The full implementation of ALPA's policy of "Contract Administration" is penciled in for 1953. The policy attempts to make contracts work on a day by day basis. They are revised as problems come up, rather than letting the problems accumulate until the annual re-negotiation of agreements.

Democracy. ALPA enters 1953 with almost an entirely new constituiton and by-laws and vows to become a truly democratic organization. 1953 will be the year when the theory is tested. If the plan is to work, the individual ALPA members must:

—Realize that ALPA is not a building at 55th and Cicero but is the Association of all of the membership wherever domiciled.

—Participate in the activities of the Association. Decisions can be representative only if the majority participate in their formation.

—Accept the decisions of the majority. Democracy and government by influence are not compatible.

—Adopt sound and workable policies. Policies, once made, will be carried out by the Association's officers. The governing bodies of ALPA must adopt policies which will not harm the membership and which are practical in application.

—Participate in the economic and social problems of the industry. The advancement of the piloting profession depends upon the growth and stability of the industry. They must take a hand in moving it forward.

Cockpit Design . . .

moved forward for idle cutoff, whereas on all other types with which the flight engineer was familiar, the forward position of the control was for full-rich mixture.

Control Location and Coding. The foregoing review of control errors suggests several types of possible corrective action. One would appear to be adequate separation of controls. Tests conducted by the Air Materiel Command, and discussed and analyzed by Chapanis,[10] show that human accuracy in reaching for a fixed point is comparatively poor. The smallest mean error was in reaching for a target directly in front of the subject at shoulder level, and in this case the error was approximately 2 in. With the target above or below shoulder level, slightly behind the subject and to the side, the error was approximately 4 in.

Chapanis points out that an average error will only cover 50 per cent of the cases, and that to be sure of covering all possible errors requires a multiplying factor of from three to four. Thus, in order to eliminate the possibility of control error by means of physical separation, spacing of from 6 to 8 in. would be required for those controls directly ahead of the pilot, and double this amount for those on side panels. Such spacing is impossible in an airplane cockpit. Therefore other measures must be taken to eliminate control confusion.

Control Motion. Control motion is just as important as control location and identification in eliminating pilot difficulties. Here the requirement is that control motions be natural and conform to basic habit patterns. The selection of natural motions is largely a matter of common sense. The first rule for naturalness in control motion is that the control move in the same direction and sense as the unit being actuated. For example, if a landing-gear control moves down to extend the landing gear there will be no confusion. If, on the other hand, the control were to move up to put the landing-gear

down, frequent errors could be expected. Also, were the control to move sideward, complete ambiguity of response could be expected, since there would be nothing to cue the pilots as to proper direction of motion.

In the case of controls for which there is no such direct association, psychological data afford a sound basis for determining what is natural. In designing such controls, the habit patterns of everyday life must be considered and utilized.

A simple example of such a habit pattern is in the use of rotary controls. Everyone uses switches of this type every day; volume controls on radios and gas valves on cooking ranges are typical examples. All these controls are designed so that clockwise rotation produces increased output — that is, the volume control on a radio turns clockwise to increase volume, etc. If this sense of motion is maintained in the cockpit, the carry-over of this habit pattern will assist in prompting correct

Attend Your Council Meetings

actuation. On the other hand, if cockpit controls are designed so that clockwise rotation produces decreased performance, a definite conflict with previously established habit patterns will exist. Training will not eliminate this conflict because of the reversion to the previous pattern whenever the pilot is not flying. To design a rotary switch for an airplane so that clockwise rotation reduces output is to invite pilot error. This is particularly true in an emergency, since under conditions of stress there is a strong tendency to revert to old habits.

Another aspect of the problem of rotary controls is their use to position visual indicators. This is a special case of the previously cited rule of controls moving in the direction and sense of the unit being actuated. Tests have shown that when such a knob is used to position a linear indicator there is complete ambiguity of response if the knob and indicator are in different planes. However, when the knob is mounted in the same plane as the indicator there is a highly consistent response pattern. From 70 to 95 per cent of the subjects tested turned the side of the knob adjacent to the indicator in the direction of the desired indicator motion. By projection, it can be seen that the operator in effect turned the knob clockwise to produce a clockwise indicator motion.

This same "clockwise-clockwise" tendency has been found in the use of a knob to position a semicircular indicator.[24] Here, however, it was found that some arrangements of knob and indicator evoked much more consistent response than other. With one arrangement, the number of test subjects supporting the clockwise-clockwise hypothesis was less than would be expected by chance. Apparently, the effect of certain arrangements is such that the presentation destroys the cues as to sense of motion. Thus in order to be sure that control motions are natural, consideration must also be given to the interpretation that will be put on the presentation. Here common sense is not enough, and psychological test data must be utilized.

Evaluation of Work Loads. In the foregoing sections of this paper problems of instrumentation and control have been considered, and it has been shown how specific measures can reduce pilot-error potential. These, while important, cover only one part of the problem. Most important is the overall design approach of considering the pilot and his capacities. Even though all of the measures discussed were to be utilized fully, the demands placed upon the pilot could still exceed human limitations, particularly with regard to the number of duties involved and the speed with which they must be performed.

In analyzing this problem, the use of time-motion studies is of value. Such studies were made on a multiengined aircraft that in the initial phases of operation had an extremely high incidence of landing accidents due to crew error. These studies revealed that from the time the aircraft entered the traffic pattern until it touched down, the copilot was required to make 116 distinct motions in 305 sec., an average of one every 2.6 sec. During one period of 90 sec., the required rate of movements was one every 1.8 sec.[25] Under normal conditions, a man can carry out such a routine with comparative ease. When, however, he is under stress in an emergency, or is suffering from fatigue, an error becomes highly probable.

In evaluating crew ability to carry work load, average performance levels cannot be assumed. Full consideration must be given to day-to-day variability in performance, and to the added effect of factors such as fatigue in producing deterioration in these levels.[26,27]

Reduction of Work Loads. Crew work loads can often be reduced by simplification of controls for functional systems. Although a discussion of the design of such systems is beyond the scope of this paper, it should be pointed out that the pilot must be considered in the original design concept, in order to avoid undue complexity in the controls.

When analysis of crew work load shows it to be approaching the limit of human capacity, despite all possible measures in control simplification, other steps must be be taken to relieve the load. If transfer of duties to another crew member is not possible, the airplane must take over the function by means of automatic control. This, of course, implies increased complexity in the machine. However, the basic goal is a man-machine combination that can operate with maximum overall efficiency. While design simplification is highly desirable for reasons of cost, weight, and maintenance, it cannot be achieved at the expense of overloading the human element. If it is acquired in this way, the cost of resulting accidents may far overbalance the saving achieved by the simplification.

Emergency Controls. In no phase of cockpit design is full consideration of the human factor so important as in the design of emergency controls. When an emergency arises, the time available for the pilot to take the necessary action is extremely short. Emergency procedures, therefore, must not be complex. Controls must be easily identifiable and readily accessible: control motion and sequence of operation should be as simple as possible. It is imperative that all control motions be completely consonant with normal habit patterns, since, as has been established, a person tends to revert to old habits under conditions of stress.

Too frequently design engineers have the attitude that it does not

matter if emergency controls are complicated or difficult to reach, since they may never be used in the life of the airplane. Far too many incidents have become accidents because of this philosophy.

Funk and Wagnalls' Dictionary defines an emergency as:

"A sudden or unexpected occurrence or condition calling for immediate action; a perplexing and pressing combination of circumstances."

The designer should at least try not to add to the pilot's perplexity.

Conclusions. Many so-called pilot errors have resulted from design that failed to consider basic human limitations. In order to eliminate such accident potential a new design philosophy is needed. Analysis of the qualities of the machine is common engineering practice; yet to maintain a sound man-machine relationship, it is also necessary to analyze the qualities of the man. Research in Human Engineering has provided the basis for implementing this approach. It remains for the designer to make full use of the available data.

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Into the Wild Blue Yonder . . .

What does a man think about, when he sits perched on air ten thousand feet above the good earth, with the power of thousands of horses at his finger tips, the roar of cataracts about him, the flaming nostrils of harnessed demons belching fire into the cold sky, with wisps of cottony clouds drifting below him, and the beautiful geometrical patchwork of God's crazyquilt draped carelessly at his feet.

As he squints into the sunset, and listens to the comforting staccato of the beam, doesn't he sometimes feel anxiety about those problems which are so uniquely his — those problems which are the most important in all the world to him and of little concern to anyone else . . . such as income for the days when his wings are clipped and the earning years have fled; protection for the loved ones in the home far down on the horizon; education for the chubby little guy who climbs on his knee and zooms tiny jets dangerously close to his ear.

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